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LESSONS LEARNED FROM RECENT RAPID IMAGING OF EARTHQUAKE RUPTURES WITH SATELLITE GEODESY

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ABSTRACT

Rapid determination of the location and extent of earthquake ruptures at the surface and at depth is helpful for disaster response, as it allows prediction of the likely area of major damage from the earthquake and can help with rescue and recovery planning. The Caltech-Jet Propulsion Laboratory (JPL) Advanced Rapid Imaging and Analysis (ARIA) project has responded to many recent large earthquakes to process geodetic data and help determine the location and extent of ruptures. With the increasing availability of near real-time data from the Global Positioning System (GPS) and other global navigation satellite system receivers in active tectonic regions, and with the shorter repeat times of many recent and newly launched radar satellites, geodetic data can now be obtained quickly after earthquakes or other disasters. We have been building an ARIA data system that can ingest, catalog, and process geodetic data and combine it with seismic analysis to estimate the fault rupture locations and slip distributions for large earthquakes that are on or near land.

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Lessons learned from recent rapid imaging of earthquake ruptures with satellite geodesy

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Rapid determination of the location and extent of earthquake ruptures at the surface and at depth is helpful for disaster response, as it allows prediction of the likely area of major damage from the earthquake and can help with rescue and recovery planning. The Caltech-Jet Propulsion Laboratory (JPL) Advanced Rapid Imaging and Analysis (ARIA) project has responded to many recent large earthquakes to process geodetic data and help determine the location and extent of ruptures. With the increasing availability of near real-time data from the Global Positioning System (GPS) and other global navigation satellite system receivers in active tectonic regions, and with the shorter repeat times of many recent and newly launched radar satellites, geodetic data can now be obtained quickly after earthquakes or other disasters. We have been building an ARIA data system that can ingest, catalog, and process geodetic data and combine it with seismic analysis to estimate the fault rupture locations and slip distributions for large earthquakes that are on or near land.

Introduction

Rapid determination of the location and extent of earthquake ruptures at the surface and at depth is helpful for disaster response, as it allows prediction of the likely area of major damage from the earthquake and can help with rescue and recovery planning. Knowledge of the rupture zones of past earthquakes can also be useful for comparing with damage measured after the earthquakes and for estimating the range of scenarios for possible future earthquakes.

The Caltech-Jet Propulsion Laboratory (JPL) Advanced Rapid Imaging and Analysis (ARIA) project has responded to many recent large earthquakes to process geodetic data and help determine the location and extent of ruptures [1]. With the increasing availability of near real-time data from the Global Positioning System (GPS) and other global navigation satellite system (GNSS) receivers in active tectonic regions, and with the shorter repeat times of many recent and newly launched radar satellites, geodetic data can now be obtained quickly after earthquakes or other disasters. We have been building an ARIA data system that can ingest,

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2016 Kaikoura Earthquake

One recent large earthquake we responded to was the 13 November 2016 (UTC) Mw 7.8 Kaikoura earthquake in the northern South Island of New Zealand [2]. The ARIA team used GPS data from GeoNet GPS network operated by GNS Science to get early estimates of the magnitude and extent of deformation from the earthquake within a few hours, showing station CMBL moving more than 2 meters horizontally, despite its location on Cape Campbell over 150 km from the epicenter of the earthquake (Fig. 1). This was the first clue that the rupture extended far to the northeast of the earthquake epicenter.

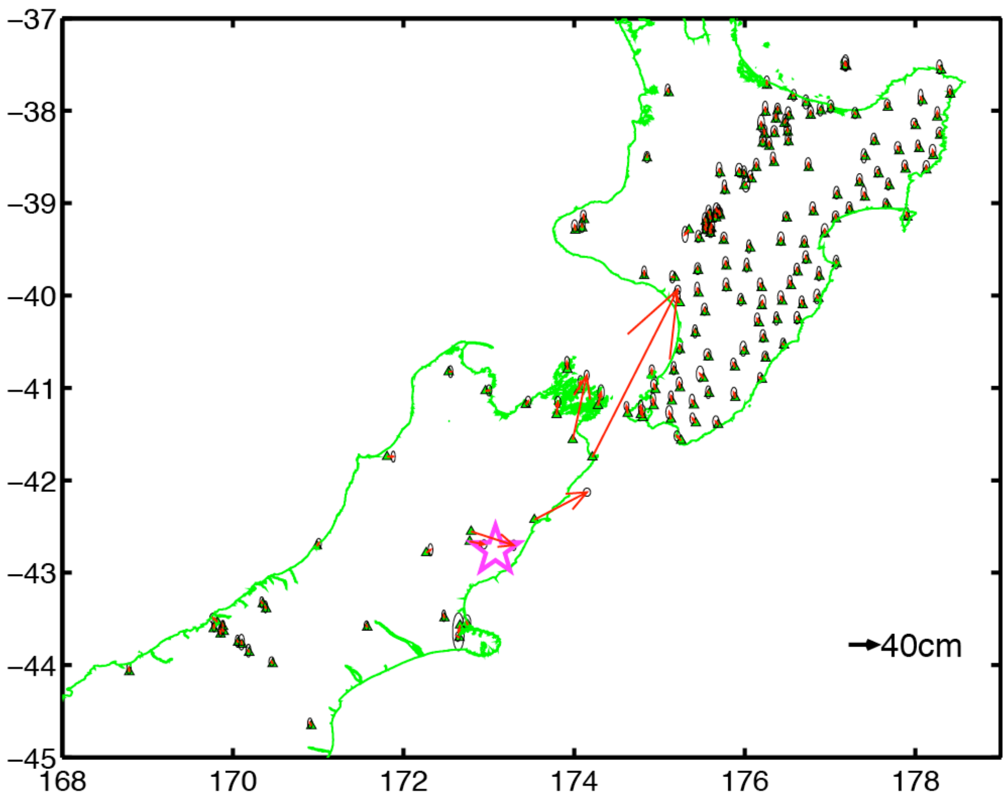

Figure 1. Preliminary GPS station offset estimates for 2016 M7.8 Kaikoura Earthquake in New Zealnd, extracted from processing with ultra-rapid orbits. Magenta star shows epicenter. Red arrows show horizontal displacements with black ellipses showing formal error estimates. Triangles show locations of GPS stations.

Synthetic Aperture Radar (SAR) data was acquired urgently over the area of the earthquake by the European Space Agency with the Copernicus Sentinel-1B satellite and by the Japanese Aerospace Exploration Agency with the ALOS-2 satellite about two days after the earthquake on 15 November (UTC). Rapid interferometric SAR (InSAR) processing by the ARIA system of the Sentinel-1A/B interferometric wide-swath images acquired on 3 and 15 November 2016 showed a complex pattern of fault ruptures extending from the epicenter to near Cape Campbell (Fig. 2).

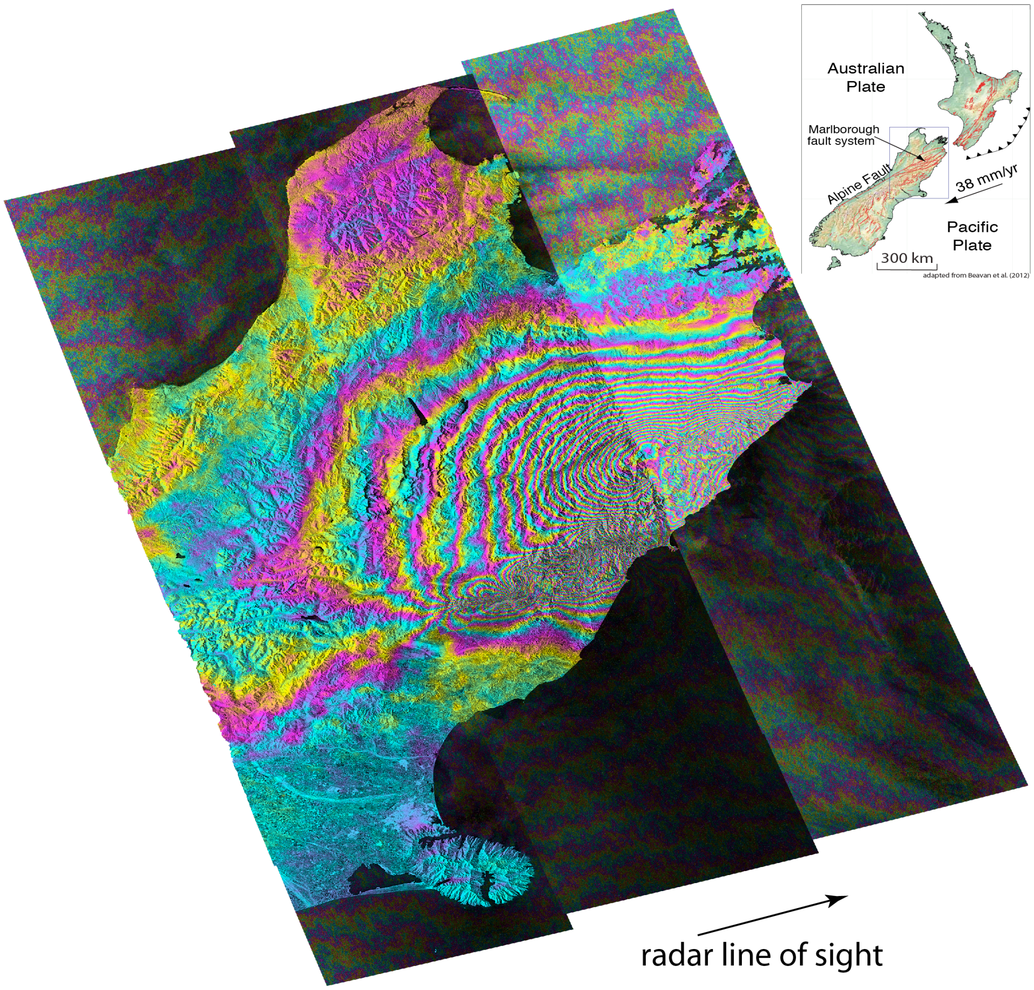

Figure 2. Sentinel-1interferogram for 2016 M7.8 Kaikoura Earthquake with 9 cm color contours, automatically processed by ARIA data system. Inset shows location of figure in New Zealand, adapted from [3].

Advanced processing of the ALOS-2 images extracted both regular InSAR measurements of deformation in the range or cross-track direction and multiple-aperture InSAR measurements of displacements in the along-track direction, providing additional information that showed a number faults moved with both strike-slip and thrust motion. Preliminary results were shared with GNS Science in New Zealand that quickly sent field teams to investigate the surface ruptures.

Conclusions

Fault ruptures of large earthquakes on or near land can be rapidly evaluated with geodetic data that supplements the information derived from more traditional seismic data. Networks of continuously recording GNSS receivers are present in many regions of high earthquake risk and can provide rapid geodetic measurements of the surface deformation due to the earthquake. Near-real time systems enable GNSS data analysis and estimates of the coseismic displacements within hours after the event. Radar satellite operators often acquire images suitable for InSAR analysis on an emergency basis as rapidly as possible after large earthquakes. Depending on where the satellites are in their orbits, the next pass over the area can be within hours to many days after the earthquake, but typically one or more satellites can acquire an image in the first four days. Data transfer to the ground and early stages of processing usually take less than a day, with the final interferogram formation taking only an hour or so. This enables an image of the earthquake deformation that usually accurately constrains the location and extent of the fault rupture if there is enough land around the rupture.

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